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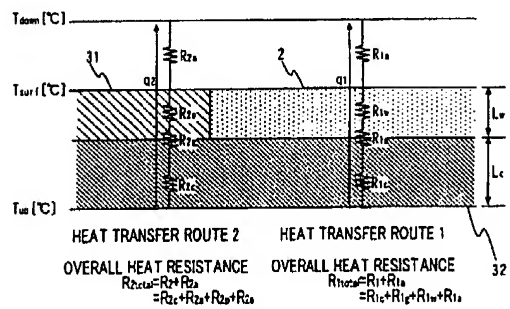
(54) APPAREIL EPITAXIAL EN PHASE VAPEUR ET PROCEDE EPITAXIAL EN PHASE VAPEUR

(54) VAPOR PHASE EPITAXIAL APPARATUS AND VAPOR PHASE EPITAXIAL METHOD

(57)
A vapor phase epitaxial apparatus comprises a sealable reaction furnace, a wafer accommodation body which is installed in the reaction furnace to dispose a wafer at a predetermined position, a gas feeding means for feeding raw gas toward the wafer, and a heating means for heating the wafer. An epitaxial film is formed on a surface of the wafer by feeding the raw gas into the reaction furnace in a high-temperature state while heating the wafer via the wafer accommodation body by the heating means in the reaction furnace. The wafer accommodation body comprises a heat flow control unit having a cavity formed for accommodating the wafer, and a heat flow transmission unit which is joined to the heat flow control unit to transfer the heat to the wafer accommodated in the cavity. The contact thermal resistance of the heat flow control unit with the heat flow transfer unit is set to be not lower than 1.0 x 10-6 m2K/W and not greater than 5.0 x 10-3 m2K/W, and the heat flow control unit is formed of a material having the thermal conductivity of not smaller than 0.5 times and not greater than 5 times of the thermal conductivity of the wafer disposed on the heat flow transfer unit.



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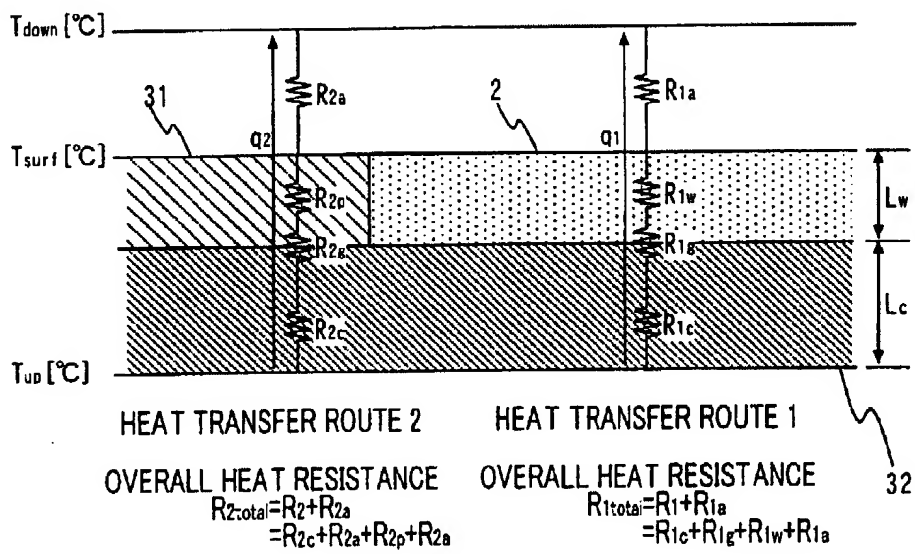


(57) Abrégé/Abstract:
A vapor phase epitaxial apparatus comprises a sealable reaction furnace, a wafer accommodation body which is installed in the reaction furnace to dispose a wafer at a predetermined position, a gas feeding means for feeding raw gas toward the wafer, and a heating means for heating the wafer. An epitaxial film is formed on a surface of the wafer by feeding the raw gas into the reaction furnace in a high-temperature state while heating the wafer via the wafer accommodation body by the heating means in the reaction furnace. The wafer accommodation body comprises a heat flow control unit having a cavity formed for accommodating the wafer, and a heat flow transmission unit which is joined to the heat flow control unit to transfer the heat to the wafer accommodated in the cavity. The contact thermal resistance of the heat flow control unit with the heat flow transfer unit is set to be not lower than 1.0×10^{-6} m^2K/W and not greater than 5.0×10^{-3} m^2K/W, and the heat flow control unit is formed of a material having the thermal conductivity of not smaller than 0.5 times and not greater than 5 times of the thermal conductivity of the wafer disposed on the heat flow transfer unit.

ABSTRACT

A vapor-phase growth apparatus includes: a reaction furnace which is hermetically closable, a wafer container which is disposed in the reaction furnace, for disposing a wafer at a predetermined position, a gas supply member for supplying a source gas toward the wafer, and a heating member for heating the wafer, wherein the apparatus is designed to form a grown film on a front surface of the wafer by supplying the source gas in a high temperature state while the heating member heats the wafer in the reaction furnace through the wafer container. The wafer container includes: a heat flow control section having a space for disposing a wafer; and a heat flow transmitting section joined to the heat flow control section, for transmitting heat to the wafer disposed in the space; and contact heat resistance R_g between the heat flow control section and the heat flow transmitting section is not less than 1.0×10^{-6} m^2K/W to not more than 5.0×10^{-3} m^2K/W, and the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 5 times to not more than 20 times that of the wafer disposed on the heat flow transmitting section.

DESCRIPTION

VAPOR-PHASE GROWTH APPARATUS AND VAPOR-PHASE GROWTH METHOD

Technical Field

The present invention relates to a vapor-phase growth apparatus and a vapor-phase growth method, for growing a thin film of compound semiconductor or the like on a surface of a wafer in a vapor phase, while heating the wafer under a supply of a source gas in a high temperature state, and in particular to material characteristics of a wafer container for disposing wafers thereon.

Background Art

Vapor-phase growth process is currently utilized in various industrial fields. Needless to say, in the vapor-phase growth, advanced uniformities in thickness, composition and doping concentration of a film grown on the wafer over the entire surface thereof are essential matters. Achievement of thermal uniformity in wafer heating is therefore recognized as the most important elementary technology as one means for realizing the aforementioned uniformities over the entire surface.

FIG. 1 is a sectional view showing an exemplary constitution of a general vapor-phase growth apparatus. As shown in FIG. 1, a vapor-phase growth apparatus 100 comprises

a reaction furnace 1, a wafer holder 3 for disposing wafers 2 thereon, a susceptor 4 for placing the wafer holder 3 thereon, a heater 5 disposed below the susceptor 4, a rotary mechanism 6 for supporting the wafer holder 3 and the susceptor 4 to allow them to rotate freely, a gas introducing duct 7 for supplying a source gas and a carrier gas therethrough, a gas exhaust duct 8 for discharging the non-reacted gas, and the like.

FIG. 9 is an enlarged view for showing a detailed construction of the wafer holder 3, where (a) is a plan view, and (b) is a sectional view taken along the line A-A in FIG. 9. In one surface of the wafer holder 3, a plurality of (six in FIG. 2) circular pocket holes 3a are formed for disposing the wafers 2 therein, to be arranged along a single circumference on the surface. The other surface of the wafer holder 3 is in contact with the susceptor 4. The wafer holder 3 may be composed of one or more members. Generally, it is composed of a single member, as shown in FIG 9.

The susceptor 4 herein is made of a material having a large coefficient of thermal conductivity (e.g., molybdenum) in order to uniformly transfer heat from the heater 5. It is also general to use graphite, molybdenum or the like, having a large coefficient of thermal conductivity for the wafer holder 3.

In the vapor-phase growth apparatus having such a structure described above, heat is transferred to the wafer 2

through the susceptor 4 and wafer holder 3 by heating the susceptor 4 from the lower side thereof by using the heater 5, to thereby heat the wafer 2 up to a predetermined temperature. Vapor-phase growth of a thin film is carried out by rotating the susceptor 4 at a predetermined number of rotation with the aid of a rotating mechanism 6 while uniformly supplying source gas and carrier gas, introduced through a gas introducing duct 7 toward the front surface of the wafer 2.

It was, however, found from an experiment of the present inventors that, in the aforementioned vapor-phase growth apparatus 100, the front surface temperature of the wafer 2 became lower than that of the wafer holder 3, and that the temperature of the circumferential portion of the wafer 2 consequently became higher than that of the central portion of the wafer 2, by the effect of the temperature of the wafer holder 3. In other words, it was found to be difficult for the conventional vapor-phase growth apparatus 100 to form a thin film with a high uniformity over the entire surface of the wafer 2 by vapor-phase growth since in-plane temperature distribution of the wafer 2 could not be uniform.

The present invention has been developed in order to solve the aforementioned problems. An object of the invention is therefore to provide a vapor-phase growth apparatus and a vapor-phase growth method which are capable of allowing a thin film to grow in a vapor phase so as to achieve a desirable uniformity over the entire surface of a wafer.

Disclosure of the Invention

In accordance with the invention, the vapor-phase growth apparatus comprises: at least a reaction furnace which can be tightly closed, a wafer container which is disposed in the reaction furnace, for disposing a wafer at a predetermined position thereon, a gas supply member for supplying a source gas toward the wafer, and a heating member for heating the wafer; the apparatus being designed to form a grown film on a front surface of the wafer by heating the wafer in the reaction furnace through the wafer container while supplying the source gas in a high temperature state, wherein the wafer container comprises: a heat flow control section having a space formed, for disposing a wafer therein; and a heat flow transmitting section which is joined to the heat flow control section, for transmitting heat to the wafer disposed in the space, and a uniform heat resistance R_g exists between flat or curved surfaces, of the heat flow control section and the heat flow transmitting section, in close proximity to each other.

According to the wafer container having such a structure, it is possible to adjust the ratio R_2/R_1 easily, where R_1 is a heat resistance in a heat transfer route from a rear surface of the heat flow transmitting section to the front surface of the wafer, and R_2 is a heat resistance in a heat transfer route from the rear surface of the heat flow transmitting section to a front surface of the heat flow control section.

Preferably, the heat resistance ratio R_2/R_1 is not less than 0.8 and not more than 1.2.

This almost equalizes the heat resistances in the individual heat transfer routes each other and thus ensures similar heat transfer during heat transfer from the rear surface of the wafer container (the rear surface of the heat flow transmitting section) toward the front surfaces of the wafer and of the wafer container (the front surface of the heat flow control section), and this consequently equalizes achievable temperatures of the surfaces of the wafer and the wafer container. This successfully prevents the surface temperature at the circumferential portion of the wafer from rising higher than the surface temperature at the center of the wafer, which is caused by temperature difference between the surfaces of the wafer and the wafer container. Thus, it becomes possible to keep a uniform in-plane temperature distribution of the wafer. As a consequence, a thin film having a desirable uniformity can grow in the vapor phase over the entire surface of the wafer.

The heat resistance R_g is not less than 1.0×10^{-6} m^2K/W and not more than 5.0×10^{-3} m^2K/W; otherwise a clearance distance between the heat flow control section and the heat flow transmitting section may be approximately uniform and in a range of 0.001mm to 1mm. Accordingly, because the heat resistance R_g comes to be approximately equal to the contact heat resistance between the heat flow transmitting section and

the wafer, it is possible to adjust the ratio R_2/R_1 easily.

Further, preferably, the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times that of the wafer disposed on the heat flow transmitting section and not more than 20 times thereof. Although it is not limited, the heat flow control section 31 may be made of any material, as far as the material has characteristics giving no adverse effect on thin film growth or on the environment of the reactor.

Preferably, the heat flow transmitting section is made of a material having a coefficient of thermal conductivity higher than that of wafer, for example, a material having a coefficient of thermal conductivity which is not less than 50W/mK and not more than 450W/mK.

For example, the heat flow control section may be made of any one of amorphous carbon, aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, and alumina; and the heat flow transmitting section may be made of any one of molybdenum, graphite, gold, and silver.

A vapor-phase growth apparatus comprising the above described structure is made to form a grown film on a front surface of the wafer by heating the wafer in the reaction furnace through the wafer container while supplying the source gas in a high temperature state, wherein a temperature difference between a front surface of the wafer container and

a front surface of the wafer during growing a thin film in vapor-phase is within 2°C. Accordingly, because it is possible to keep a uniform in-plane temperature distribution of the wafer, a thin film having a desirable uniformity can be grown in the vapor phase over the entire surface of the wafer.

Next, the progress that the present invention has been developed will be described, as follows.

As for a reason why the surface temperature of the wafer 2 tends to become lower than that of the wafer holder 3, the present inventors placed a focus on the difference between heat transfer routes inside the wafer 2 and wafer holder 3. That is, the present inventors considered that because the wafer 2 and wafer holder 3 generally differ from each other in materials, so that the same heat transfer cannot be performed in the routes. This causes a difference between achievable surface temperatures of the wafer and the wafer holder.

FIG. 10 is a schematic view showing heat resistances in the wafer 2 and wafer holder 3. In FIG. 10, T_{up} denotes rear surface temperature of the wafer holder 3, T_{surf} denotes a front surface temperature of the wafer 2 or wafer holder 3, and T_{down} denotes a temperature at an imaginary plane (referred to as "virtual boundary plane", hereinafter) set at a position being away from the surfaces of the wafer 2 and wafer holder 3 by a predetermined distance. As shown in FIG. 10, heat transfer toward the front surface of the wafer 2 is established along a heat transfer route 1 which originates from the rear surface of the wafer holder 3 and is directed through the wafer holder

3 itself and the wafer 2 to reach the virtual boundary plane, and heat transfer toward the front surface of the wafer holder 3 is established along a heat transfer route 2 which originates from the rear surface of the wafer holder 3 and is directed through the wafer holder 3 itself to reach the virtual boundary plane. As described above, the wafer 2 and wafer holder 3 differ from each other in the heat transfer route toward the respective surfaces thereof.

That is, as known from the schematic view of heat resistance of the wafer 2 and wafer holder 3 shown in FIG. 10, the heat resistance R_1 for the heat transfer route 1 is equal to the sum of heat resistance R_{1c} for the portion of wafer holder 3, the contact heat resistance R_{1g} between the wafer holder 3 and wafer 2, and the heat resistance R_{1w} for the portion of wafer 2; and the heat resistance R_2 for the heat transfer route 2 is equal to the heat resistance R_{2c} for the portion of wafer holder 3.

By the way, heat resistance R is given by the equation (1) below:

$$R = L/k \qquad (1)$$

R [m^2K/W] : a heat resistance

L [m] : a thickness of a material in the direction of heat flow

k [W/m·K] : a coefficient of thermal conductivity

Heat resistances R_1 and R_2 are then expressed by the equations below:

$R_1 = R_{1c} + R_{1g} + R_{1w} = L_c/k_{1c} + R_{1g} + L_w/k_{1w}$ (2)

$R_2 = R_{2c} = L_c/k_{2c} + L_w/k_{2c}$ (3)

$(k_{1c}=k_{2c})$

It is to be noted now that a relation can be written as $L_w/k_{1w}>L_w/k_{2c}$ because coefficient of thermal conductivity k_{1w} of the wafer 2 (InP, GaAs, etc.) is extremely smaller than coefficient of thermal conductivity k_{2c} of the wafer holder 3 (graphite, molybdenum, etc.), and contact heat resistance R_{1g} arises at the contact plane between the wafer 2 and wafer holder 3, so that R_2 is apparently smaller than R_1.

$R_1 > R_2$ (4)

It is also known that heat transfer is subject to heat flux in the heat transfer route. The heat flux generally refers to as the amount of energy (heat flow) flowing in a unit area (unit: m^2), and is given by equation (5) below:

$q = -1/R_{total}\ (T_{down} - T_{up})$ (5)

q [W/m^2] : a heat flux

R_{total} [m^2K/W] : an overall heat transfer

T_{up} [K] : an upstream temperature

T_{down} [K] : a downstream temperature.

In FIG. 10, overall heat resistances R_{1total} and R_{2total} in the heat transfer routes 1 and 2 are given by the equations below:

$R_{1total} = R_1 + R_{1a}$ (6)

$R_{2total} = R_2 + R_{2a}$ (7)

(where, $R_{1a}=R_{2a}$)

The foregoing equations (4), (6) and (7) give a relation of $R_{1total} > R_{2total}$. Therefore, the heat flux q_1 in the heat transfer route 1 becomes smaller than the heat flux q_2 in the heat transfer route 2.

$$q_2 > q_1 \qquad (8)$$

Furthermore, the heat fluxes q_1 and q_2 can be represented as the equations below using the surface temperature T_{1surf} of the wafer 2 and the surface temperature T_{2surf} of the wafer holder 3:

$$q_1 = -(T_{down} - T_{1surf})/R_{1a} \qquad (9)$$

$$q_2 = -(T_{down} - T_{2surf})/R_{2a} \qquad (10)$$

It is derived from the foregoing equations (8), (9) and (10) that the surface temperature T_{1surf} of the wafer 2 is lower than the surface temperature T_{2surf} of the wafer holder 3.

$$T_{2surf} > T_{1surf} \qquad (11)$$

It was thus found that, in the conventional vapor-phase growth apparatus, the difference between the surface temperatures T_{1surf} and T_{2surf} is caused by a large difference in the coefficients of thermal conductivity between the wafer 2 and wafer holder 3.

The present inventors therefore studied a method of reducing the difference between the surface temperature T_{1surf} of the wafer 2 and the surface temperature T_{2surf} of the wafer

holder 3, and based on the above equations (5) to (10), and reached an idea that close equalization of the heat resistances R_1 and R_2 in the individual heat transfer routes would be successful (that is, to set heat resistance ratio R_2/R_1 close to 1).

The present inventors has found a method in which the wafer holder 3 is composed of two members, i.e., a heat flow control section 31 and a heat flow transmitting section 32.

In the case, the schematic view of heat resistance is shown in FIG. 3, and a heat resistance R_1 and a heat resistance R_2 are given by the equations below:

$$R_1 = R_{1c} + R_{1g} + R_{1w} = L_c/k_{1c} + R_{1g} + L_w/k_{1w} \qquad (12)$$

(equivalent to the equation (2))

$$R_2 = R_{2c} + R_{2g} + R_{2w} = L_c/k_{2c} + R_{2g} + L_w/k_{2p} \qquad (13)$$

$(k_{1c}=k_{2c})$

That is, it is possible to bring near the heat resistance values R_1 and R_2 to each other, by bringing the value of contact heat resistance R_{1g} between the wafer 2 and the heat flow transmitting section 32 near the value of contact heat resistance R_{2g} between the heat flow control section 31 and the heat flow transmitting section 32 and also by bringing the value of coefficient of thermal conductivity k_{1w} of the wafer 2 near the value of coefficient of thermal conductivity k_{2p} of the heat flow control section 31.

The present invention has been developed based on the

aforementioned findings, and is to provide a vapor-phase growth apparatus 100 in which the wafer holder 3 includes: a heat flow control section having a space formed, for disposing a wafer 2 therein; and a heat flow transmitting section which is joined to the heat flow control section, for transmitting heat to the wafer disposed in the space, and a uniform heat resistance R_{2g} exists between flat or curved surfaces, of the heat flow control section and the heat flow transmitting section, in close proximity to each other, so that the ratio R_2/R_1, is not less than 0.8 and not more than 1.2.

In the present invention, the heat resistance R_g may be not less than 1.0×10^{-6} m^2K/W and not more than 5.0×10^{-3} m^2K/W; otherwise a clearance distance between the heat flow control section and the heat flow transmitting section may be approximately uniform and in a range of 0.001mm to 1mm. Accordingly, it is possible to obtain approximately equal contact heat resistances R_{1g} and R_{2g}. Further, the heat flow control section may be made of a material having a coefficient of thermal conductivity which is not less than 0.5 times that of the wafer disposed on the heat flow transmitting section and not more than 20 times thereof, to bring the value of coefficient of thermal conductivity k_{1w} of the wafer 2 near the value of coefficient of thermal conductivity k_{2p} of the heat flow control section 31.

Although the heat resistance ratio R_2/R_1 can be approximated to 1 also by raising a value of L_w or L_c in the

equations (12) and (13), this is less feasible due to problems in temperature control, in space efficiency of the apparatus and in costs, so that a material of the heat flow control section 31 was selected such as one having a coefficient of thermal conductivity close to that of the wafer 2, as a more practical strategy.

Brief Description of the Drawings

FIG. 1 is a sectional view showing a schematic construction of the vapor-phase apparatus according to the present embodiment;

FIG. 2 is an enlarged views showing a detailed construction of the wafer holder 3 which is composed of a heat flow control section and a heat flow transmitting section, where (a) is a plan view, and (b) is a sectional view taken along the line A-A;

FIG. 3 is a schematic view for explaining heat resistance of the wafer 2 and wafer holder 3 in the case where the wafer holder 3 is composed of a heat flow control section and a heat flow transmitting section;

FIG. 4 is a schematic analytical model view showing a region around the wafer 2 and wafer holder 3 of the vapor-phase growth apparatus 100 according to the embodiment;

FIG. 5 shows an analytical result of temperature distribution inside the wafer and wafer holder in the embodimenta wafer holder which is composed of a heat flow

control section and a heat flow transmitting section is used;

FIG. 6 shows an analytical result of temperature distribution inside the wafer and wafer holder in a comparative embodiment where a graphite-made wafer holder is used;

FIG. 7 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the embodiment; and

FIG. 8 shows analytical results of surface temperature distribution of the wafer and wafer holder in the comparative embodiment.

FIGS. 9 is an enlarged views showing a detailed construction of an earlier developed wafer holder 3, where (a) is a plan view, and (b) is a sectional view taken along the line A-A; and

FIG. 10 is a schematic view for explaining heat resistance of the wafer 2 and wafer holder 3 in an earlier developed vapor-phase growth apparatus.

Best Mode for Carrying out the Invention

An embodiment of the vapor-phase growth apparatus (MOCVD apparatus) of the present invention will be described below referring to the attached drawings.

FIG. 1 is a sectional view showing a schematic construction of the vapor-phase growth apparatus according to the present embodiment. FIG. 2 is an enlarged view showing a

detailed construction of the wafer holder 3 in the present invention, where (a) is a plan view, and (b) is a sectional view taken along the line A-A.

In the earlier development, the wafer holder 3 which is a wafer container was made of a material having a large coefficient of thermal conductivity, such as graphite. The vapor-phase growth apparatus of the embodiment is different from the earlier development in that the wafer container comprises: a heat flow transmitting section 32 made of a material having a large coefficient of thermal conductivity, such as graphite; and a heat flow control section 31 made of amorphous carbon (abbreviated as α-carbon, hereinafter) or the like, having a coefficient of thermal conductivity relatively near that of the wafer.

As shown in FIG. 1, the vapor-phase growth apparatus 100 comprises a reaction furnace 1, a wafer holder 3 for disposing wafers 2 thereon, a susceptor 4 for placing the wafer holder 3 thereon, a heater 5 disposed below the susceptor 4, a rotary mechanism 6 for supporting the wafer holder 3 and the susceptor 4 in a freely rotatable manner, a gas introducing duct 7 for supplying a source gas and a carrier gas therethrough, and a gas exhaust duct 8 for discharging the non-reacted gas.

Each of wall members of the vapor-phase growth apparatus 100 is typically composed of a stainless steel. The gas introducing duct 7 is disposed at the vicinity of the center

portion of the upper wall member, and introduces a Group XIII (IIIB) source gas such as trimethyl indium (TMI), trimethyl aluminum (TMAl) or trimethyl gallium (TMG); a Group XV (VB) source gas such as arsine (AsH_3) or phosphine (PH_3); and an inert gas such as hydrogen (H_2) as a carrier gas into the reaction furnace.

The wafer holder 3 is composed of a member which comprises a heat flow transmitting section 32 made of graphite and formed in a disk shape, and a heat flow control section 31 made of amorphous carbon which is formed on the heat flow transmitting section 32 as a body. The wafer holder 3 is placed on the susceptor 4. In the heat flow control section 31, a plurality of (six in FIG. 2) circular pocket holes (recesses) 3a for containing the wafers 2 therein, are formed along a single circumference. The susceptor 4 is composed of a material having a large coefficient of thermal conductivity (e.g. molybdenum) in order to uniformly transfer heat from the heater 5, and is supported by the rotary mechanism 6 in a freely rotatable manner. Below the susceptor 4, the heater 5 for heating the wafer 2 is concentrically arranged.

Although it was a general practice to use graphite or molybdenum having a large coefficient of thermal conductivity, for the wafer holder 3 in the earlier developed vapor-phase growth apparatus, the wafer holder 3 in the vapor-phase growth apparatus 100 according to the present embodiment comprises a heat flow transmitting section 32 made of graphite, and a heat

flow control section 31 made of α-carbon.

Concretely, by using α-carbon having a coefficient of thermal conductivity of about 10 W/m·K for the heat flow control section 31, the coefficient of thermal conductivity of the wafer 2 placed on the wafer holder 3 and the coefficient of thermal conductivity of the wafer holder 3 come to be approximately equal to each other. Because the coefficient of thermal conductivity of an InP wafer is 14.3 W/m·K which is estimated as approximately 0.7 times that of α-carbon.

The clearance between the heat flow control section 31 and the heat flow transmitting section 32 is approximately uniform in a range of 0.01mm to 1mm, and the contact heat resistance thereof is not less than 1.0×10^{-6} m^2K/W and not more than 1.0×10^{-1} m^2K/W.

Such a construction almost equalizes the heat resistances for the individual heat transfer routes from the heater 5 to the front surface of the wafer 2 and to the front surface of the wafer holder 3, through the susceptor 4 and wafer holder 3, and this consequently equalizes achievable temperatures of the surfaces of the wafer 2 and of the wafer container 3. This successfully prevents the surface temperature at the circumferential portion of the wafer from rising higher than the surface temperature at the center of the wafer, which is caused by temperature difference between the surfaces of the wafer 2 and the wafer container 3. Thus, it becomes possible to keep a uniform in-plane temperature distribution of the

wafer 2.

The heat flow transmitting section 32 may be made of not only graphite but also, for example, molybdenum, gold, silver or the like. The heat flow control section 31 may be made of not only α-carbon but also aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, alumina or the like.

The gas exhaust duct 8 is disposed at the bottom of the reaction furnace 1. A source gas introduced into the reaction furnace 1 from an introduction port through the gas introducing duct 7 is decomposed in the upstream side of the reaction furnace, and is then flown to the downstream side to form a thin film on the wafers 2. The non-reacted source gas is discharged out through an exhaust port and the gas exhaust duct 8, together with the carrier gas.

Although not shown in the drawings, water-cooled jackets are provided typically on the outer periphery of the rotary mechanism 6 and on the lower outside wall of the reaction furnace. These water-cooled jackets and heater 5 control the temperature inside the reaction furnace 1.

In the vapor-phase growth apparatus 100 having the above-described construction, heat is transferred to the wafer 2 through the susceptor 4 and the wafer holder 3 under heating of the susceptor 4 from the lower side thereof by using heater 5, to thereby heat the wafer 2 to a predetermined temperature. Vapor-phase growth of a thin film is carried out by rotating

the susceptor 4 at a predetermined number of rotation with the aid of a rotating mechanism 6 while uniformly supplying a source gas and carrier gas introduced through a gas introducing duct 7 to the upper surface of the wafers 2. Since temperatures of the upper surface of the wafer 2 and the upper surface of the wafer holder 3 (heat flow control section 31) herein become almost equivalent each other, the in-plane temperature distribution of the wafer 2 becomes uniform, and this allows vapor-phase growth of a thin film having an excellent uniformity.

Next paragraphs will describe simulation results of heat transfer examined using the vapor-phase growth apparatus of the embodiment, in order to clarify specific features of the present invention. Also a similar simulation of heat transfer using the earlier developed vapor-phase growth apparatus was carried out as a comparative embodiment.

In the simulation, the wafer 2 and the vicinity thereof in the vapor-phase growth apparatus 100 were modeled, and three-dimensional heat transfer analysis based on the finite volume method was carried out. A wafer holder 3 which includes a heat flow transmitting section 32 made of graphite and a heat flow control section 31 made of α-carbon, was used in the embodiment, and a graphite-made wafer holder 3 was used in a comparative embodiment.

FIG. 4 is a schematic analytical model view showing a region around the wafer 2 and wafer holder 3 (having an

outward width of 10 mm from the periphery of wafer) of the vapor-phase growth apparatus 100. As shown in FIG. 4, a distance from the bottom surface of the wafer holder 3 to the wafer 2 was defined as 6.4 mm. The wafer 2 was an InP wafer having a thickness of 0.5 mm and an inner diameter of 50 mm (2 inches), and the reaction furnace 1 was conditioned to have a hydrogen atmosphere. The number of meshes for the analysis was defined as about 6,000,000 meshes.

The contact heat resistance (R_{1g}) between the wafer 2 and the heat flow transmitting section 32, and the contact heat resistance (R_{2g}) between the heat flow control section 31 and the heat flow transmitting section 32 were defined as 2.0×10^{-4} m^2K/W. It is to be noted that the contact heat resistance R_{1g} is affected by the flatness, surface roughness and coefficient of thermal diffusion of the material, of the members contacting with each other, and it can further be reduced by reducing the distance between the contact surfaces.

The analytical conditions further includes boundary conditions of 45°C for the boundary plane of hydrogen gas located 35 mm above the wafer 2, and of 650 °C for the boundary (rear surface) of the wafer holder 3.

In the heat transfer analysis of this model, hydrogen was approximately assumed as a solid, since hydrogen having a small Prandtl number shows thermal diffusion which prevails over viscous diffusion, and since effects of advection is negligible in a region having a relatively small Reynolds

number in the laminar flow region.

The following physical property values were used for the present analysis.

TABLE 1

	HYDROGEN	GRAPHITE (COMPARATIVE EXAMPLE)	α-CARBON (EXAMPLE)	InP
DENSITY [kg/m^3]	0.00259	2000	1550	4787
SPECIFIC HEAT [J/kgK]	14500	1000	1000	368
COEFFICIENT OF THERMAL CONDUCTIVITY [W/m·K]	0.4048	100	10	14.3

FIG. 5 shows an analytical result of temperature distribution within the wafer 2 and wafer holder 3 in an Example where a wafer holder 3 comprising a heat flow control section and a heat flow transmitting section is used, and FIG. 6 shows an analytical result of temperature distribution within the wafer 2 and wafer holder 3 in a Comparative Example where an α-carbon-made wafer holder 3 is used. It is to be noted that FIGS. 5 and 6 show enlarged views of the boundary portion between the wafer 2 and wafer holder 3 in order to clarify the analytical results.

FIG. 7 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the Example, and FIG. 8 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the Comparative Example. It is to be noted that FIGS. 7 and 8 show the surface temperature measured at positions along the

direction of diameter assuming the center of the wafer as zero.

In the Example, as shown in FIG. 5, the temperature gradients in the wafer 2 and the heat flow transmitting section 32 are almost equivalent, and a parallel and uniform isothermal lines distribution is observed in the wafer 2. On the other hand in Comparative Example, as shown in FIG. 6, the temperature gradients in the wafer 2 and the upper portion of the wafer holder 3 are quite different from each other. In the wafer 2, temperature increases toward the peripheral portion from the central portion. This indicates that, in Example, similar heat transfer is established even if the heat transfer route differs.

Heat resistance ratio R_2/R_1 was found to be 1.06 in Example, but 0.24 in Comparative Example.

It was also found for Example shown in FIG. 7 that each of the front surface temperatures of the wafer and of the wafer holder (heat flow control section) was the same at 634.0°C, whereas it was found for Comparative Example shown in FIG. 8 that the front surface temperature of the wafer was 636.0°C, and the front surface temperature of the wafer holder was 638.0°C. That is, the difference between them is about 2.0°C. It was thus made clear that the present Example showed a smaller difference in the front surface temperatures between the circumferential portion (22 to 25 mm) and the central portion (around 0) of the wafer 2, and that the in-plane temperature distribution of the wafer 2 was improved to attain

uniformity.

As described above, Example was successful in keeping uniformity of the in-plane temperature distribution of the wafer 2 because the surface temperature in the circumferential portion of the wafer 2 became less likely to be affected by the surface temperature of the wafer holder 3. As a result, the present invention is successful in proceeding vapor-phase growth of a thin film which has a desirable uniformity over the entire surface of the wafer.

According to the present embodiment, because the vapor-phase growth apparatus 100 was designed so that the wafer container comprises: a heat flow control section having a space formed, for disposing a wafer therein; and a heat flow transmitting section which is joined to the heat flow control section, for transmitting heat to the wafer disposed in the space; and the contact heat resistance between the heat flow transmitting section and the heat flow control section is not less than 1.0×10^{-6} m^2K/W and not more than 5.0×10^{-3} m^2K/W, and the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times that of the wafer disposed on the heat flow transmitting section and not more than 20 times thereof. As a result, this almost equalizes the heat resistances for the individual heat transfer routes to each other during heat transfer from the rear surface of the wafer container (the rear surface of the heat flow transmitting section) to the front surfaces of the

wafer and of the wafer container (the front surface of the heat flow control section).

That is, because heat transfer is performed according to almost equivalent heat flux, it is possible equalize achievable temperatures of the front surfaces of the wafer and of the wafer container. This successfully prevents the front surface temperature at the circumferential portion of the wafer from rising higher than the surface temperature at the center of the wafer which is caused by temperature difference between the surfaces of the wafer and the wafer container, and makes it possible to keep a uniform in-plane temperature distribution of the wafer. As a result, the present invention is successful in proceeding vapor-phase growth of a thin film which has a desirable uniformity over the entire surface of the wafer.

Industrial Applicability

Although the foregoing paragraphs explained the present invention conceived by the present inventors mainly referring to a vertical high-speed-rotating-type, vapor-phase growth apparatus on which the background of the invention stands, the present invention is by no means limited to the above type, and instead applicable to any general vapor-phase growth apparatuses such as those based on face-down system, lateral type, autorotation/revolution system, and the like.

The present invention is applicable not only to the case

where InP wafer is used, but also to cases where a thin film is grown on wafers such as being comprised of Si, GaAs, GaN, sapphire, glass, ceramic, and the like. In these cases, it is also allowable to alter a material composing the wafer holder 3 (or heat flow control section 31) depending on the wafer to be used.

CLAIMS

1. A vapor-phase growth apparatus comprising:

a reaction furnace which is hermetically closable,

a wafer container which is disposed in the reaction furnace, for disposing a wafer at a predetermined position,

a gas supply member for supplying a source gas toward the wafer, and

a heating member for heating the wafer,

wherein the apparatus is designed to form a grown film on a front surface of the wafer by supplying the source gas in a high temperature state while the heating member heats the wafer in the reaction furnace through the wafer container,

the wafer container comprises a heat flow control section having a space for disposing the wafer, and a heat flow transmitting section joined to the heat flow control section, for transmitting heat to the wafer disposed in the space, and

a heat resistance R_g at a flat or curved surface where the heat flow control section and the heat flow transmitting section are close to each other is uniform.

2. The vapor-phase growth apparatus as claimed in claim 1, wherein a ratio R_2/R_1 is not less than 0.8 to not more than 1.2, where R_1 is a heat resistance for a heat transfer route from a rear surface of the heat flow transmitting section to the front surface of the wafer, and R_2 is a heat resistance for

a heat transfer route from the rear surface of the heat flow transmitting section to a front surface of the heat flow control section.

3. The vapor-phase growth apparatus as claimed in claim 1 or 2, wherein the heat resistance R_g is not less than 1.0×10^{-6} m^2K/W to not more than 5.0×10^{-3} m^2K/W.

4. The vapor-phase growth apparatus as claimed in any one of claims 1 to 3, wherein a clearance distance between the heat flow control section and the heat flow transmitting section is uniform and the clearance is in a range of 0.001mm to 1mm.

5. The vapor-phase growth apparatus as claimed in any one of claims 1 to 4, wherein the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times to not more than 20 times that of the wafer disposed on the heat flow transmitting section.

6. The vapor-phase growth apparatus as claimed as claimed in any one of claims 1 to 5, wherein the heat flow transmitting section is made of a material having a coefficient of thermal conductivity which is not less than 50W/mK to not more than 450W/mK.

7. The vapor-phase growth apparatus as claimed in any one of claims 1 to 6, wherein the heat flow control section is made of a material selected from a group consisting of amorphous carbon, aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, and alumina, and

the heat flow transmitting section is made of a material selected from a group consisting of molybdenum, graphite, gold, and silver.

8. A vapor-phase growth method comprising:

using a vapor-phase growth apparatus comprising a reaction furnace which is hermetically closable, a wafer container disposed in the reaction furnace, for disposing a wafer at a predetermined position, a gas supply member for supplying a source gas toward the wafer, and a heating member for heating the wafer; and

forming a thin film on a front surface of the wafer by supplying the source gas in a high temperature state while the heating member heats the wafer in the reaction furnace through the wafer container,

wherein a temperature difference between a front surface of the wafer container and a front surface of the wafer is within 2°C in the forming.

FIG.1

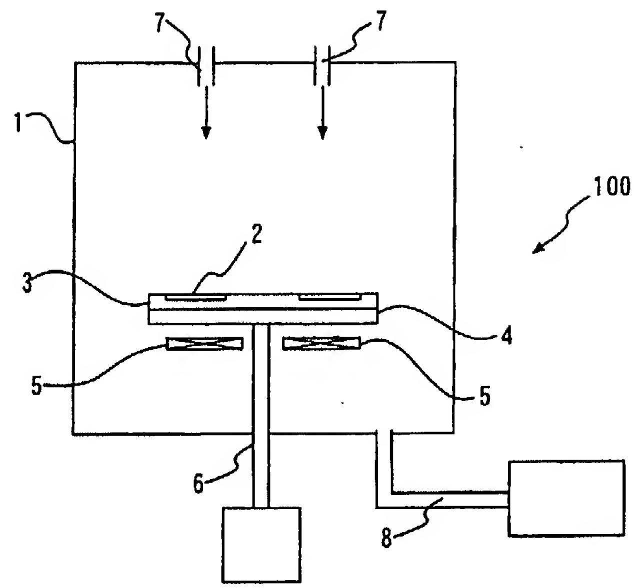


FIG.2

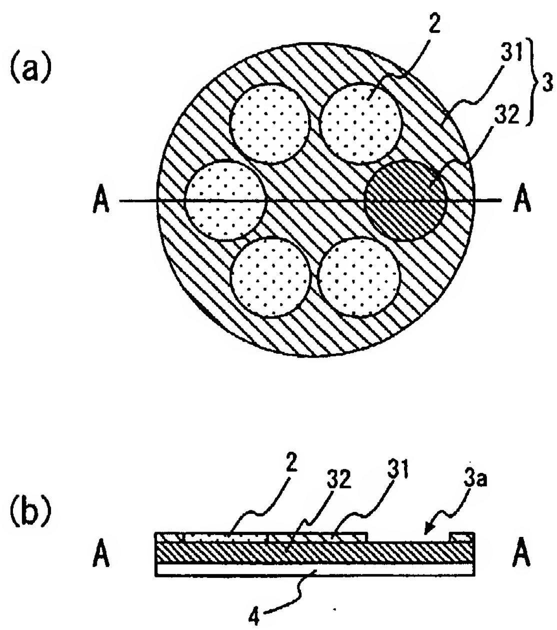
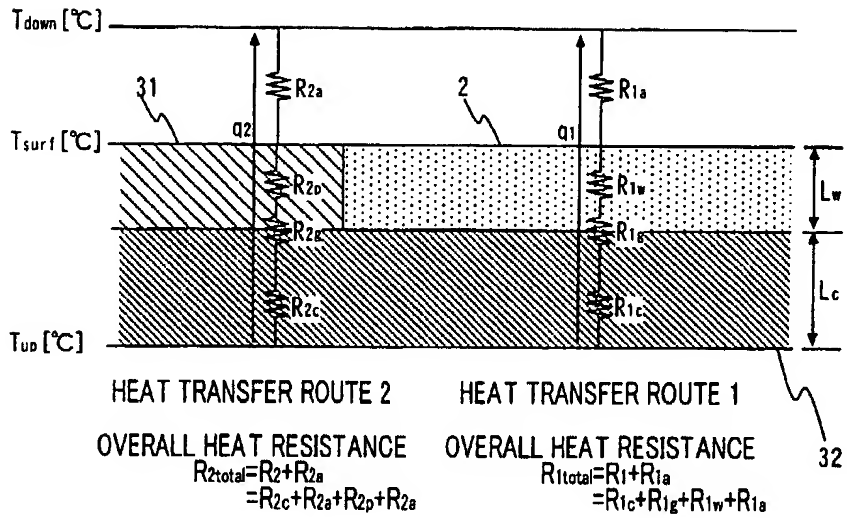
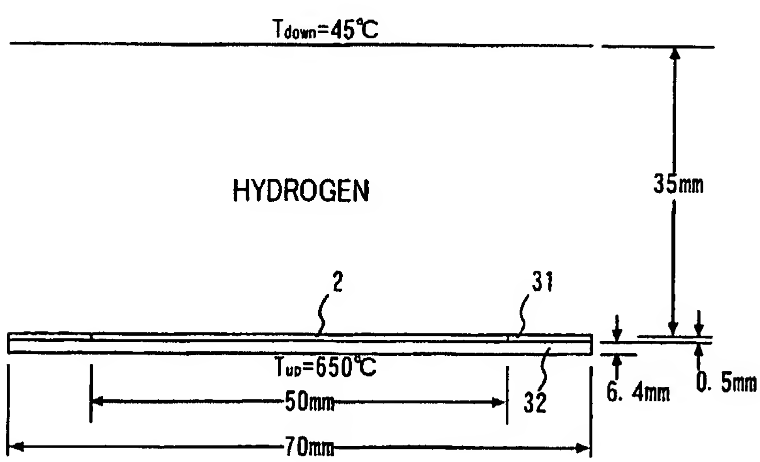


FIG.3



T_{down} [℃]
T_{surf} [℃]
T_{up} [℃]
31
2
q2
q1
R_{2a}
R_{1a}
R_{2p}
R_{2g}
R_{2c}
R_{1w}
R_{1g}
R_{1c}
L_w
L_c
HEAT TRANSFER ROUTE 2
HEAT TRANSFER ROUTE 1
OVERALL HEAT RESISTANCE
$R_{2total}=R_2+R_{2a}$
$=R_{2c}+R_{2a}+R_{2p}+R_{2a}$
OVERALL HEAT RESISTANCE
$R_{1total}=R_1+R_{1a}$
$=R_{1c}+R_{1g}+R_{1w}+R_{1a}$
32

FIG.4



T_{down}=45℃
HYDROGEN
35mm
2
31
T_{up}=650℃
50mm
32
6. 4mm
0. 5mm
70mm

FIG.5

RANGE : 634℃-638℃/40DIV
RESOLUTION : 0.1℃/DIV

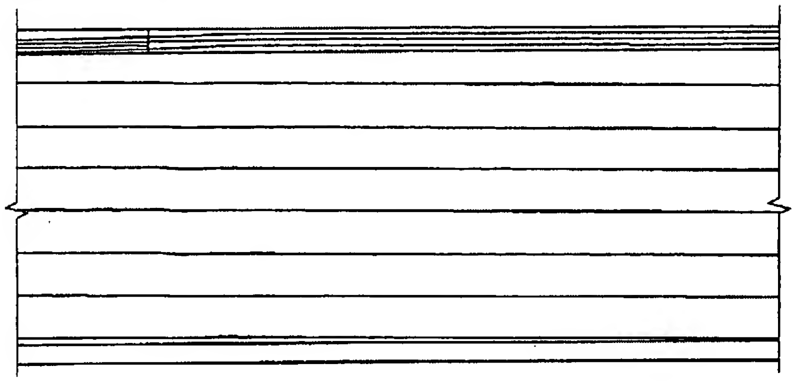


FIG.6

RANGE : 636℃-640℃/40DIV
RESOLUTION : 0.1℃/DIV

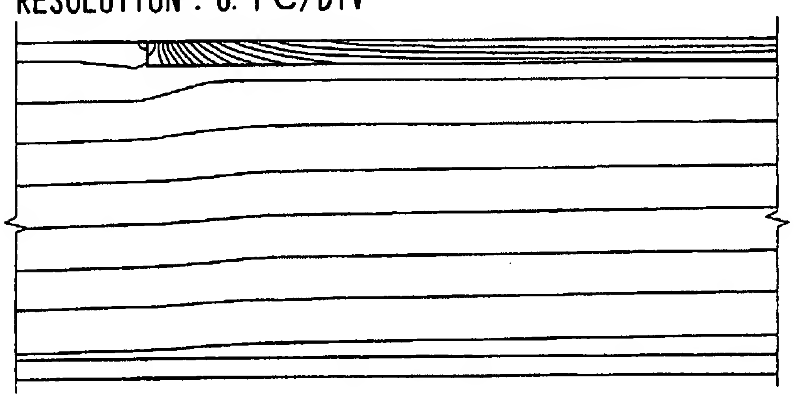


FIG.7

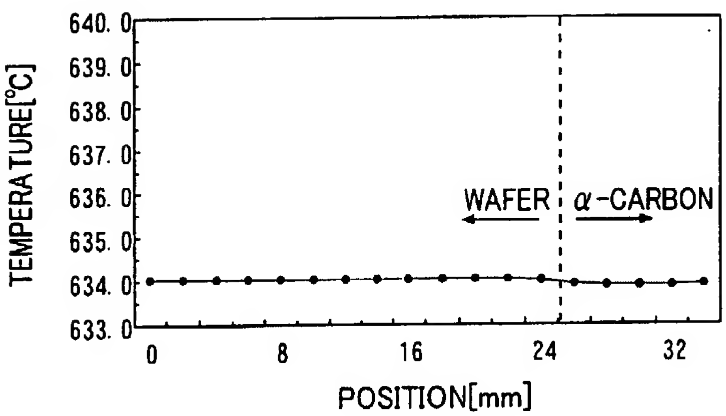
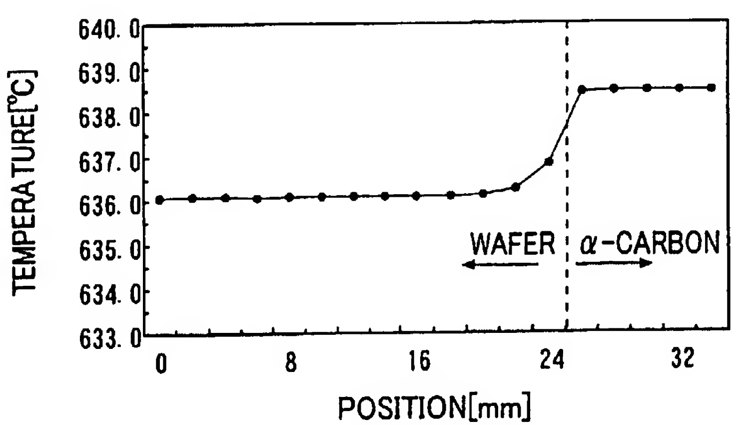

640.0
639.0
638.0
637.0
636.0
635.0
634.0
633.0
TEMPERATURE[°C]
WAFER
α-CARBON
0
8
16
24
32
POSITION[mm]

FIG.8


640.0
639.0
638.0
637.0
636.0
635.0
634.0
633.0
TEMPERATURE[°C]
WAFER
α-CARBON
0
8
16
24
32
POSITION[mm]

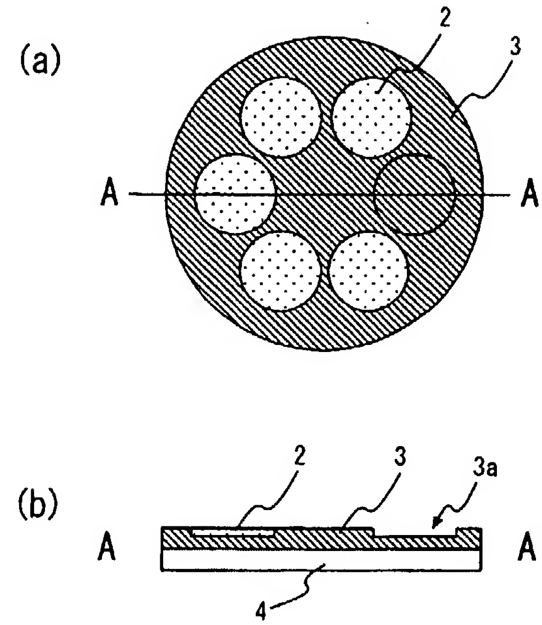
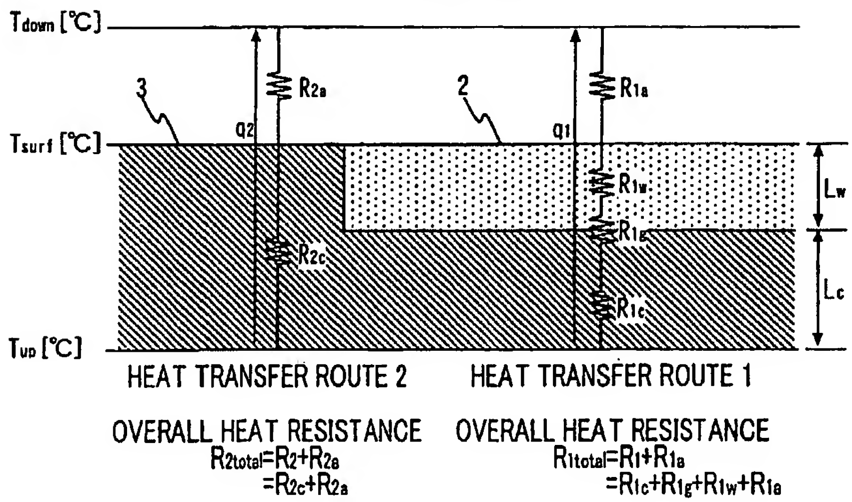

(a)
2
3
A
A
(b)
2
3
3a
A
A
4

FIG.9

FIG.10


Tdown [℃]
Tsurf [℃]
Tup [℃]
3
2
R2a
R1a
Q2
Q1
R1w
R1g
R2c
R1c
Lw
Lc
HEAT TRANSFER ROUTE 2
HEAT TRANSFER ROUTE 1
OVERALL HEAT RESISTANCE
R2total=R2+R2a
=R2c+R2a
OVERALL HEAT RESISTANCE
R1total=R1+R1a
=R1c+R1g+R1w+R1a

DS

EUROPEAN PATENT OFFICE

Patent Abstracts of Japan

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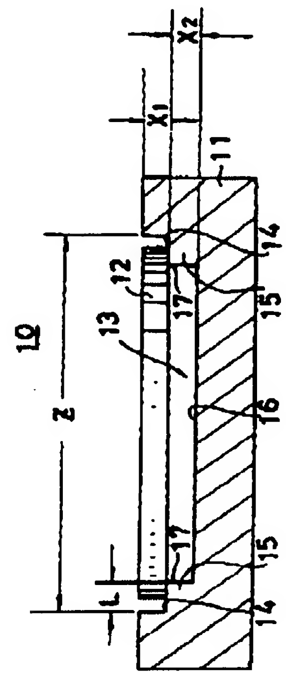
APPLICATION NUMBER : 57155509



APPLICANT : TOSHIBA CORP;

INVENTOR : KUBOTA HIROYASU;

INT.CL. : H01L 21/205 H01L 21/31

TITLE : HEATING BLOCK

ABSTRACT : PURPOSE: To prevent a processed material from slipping and make vapor phase growth easy by a method wherein an opening which has a diameter a little bit larger than that of the processed material is formed on a block and inside the opening an approximately circular step by which the processed material is supported is provided.

CONSTITUTION: An opening 13 which has a diameter Z a little bit larger than that of a processed material 12 such as a semiconductor wafer is formed on a prescribed domain of a basic body 11 of a heating block 10. An approximately circular step 15 which is protruded inside the opening 13 is formed in order to provide an approximately circular supporting surface 14 which supports the processed material 12 from the bottom. The basic body is made of a material such as carbon and of a carbon silicate layer of thickness approximately 100μm which is formed on the carbon material.

D5

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⑤加熱基台

㉑特　　願　昭57—155509
㉒出　　願　昭57(1982) 9 月 7 日

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明　　細　　書

1. 発明の名称

加　熱　基　台

2. 特許請求の範囲

基体の所定領域に被処理体の径よりも僅かに大きい径の開口部を有し、該開口部の内縁に略環状に前記被処理体の支持面を形成して突出した段部を有し、かつ、該開口部内に略平坦面からなる床面を有してなることを特徴とする加熱基台。

3. 発明の詳細な説明

〔発明の技術分野〕

本発明は、加熱基台に関する。

〔発明の技術的背景とその問題点〕

従来、シリコンウエハ等の被処理体に気相成長処理を施す場合、例えば、第1図に示す如くシリコン等からなる基体1に球面状の凹部2を形成し、この凹部2に半導体ウエハ等の被処理体3を載置し、これを所定の炉内に設置することにより行っている。しかしながら、このような加熱基台4を用いるものでは、被処理体3の径が大きくなるとこれに合わせて凹部2の径を大きくすると、気相成長処理の際のスリップの発生率が高くなる欠点がある。また、第2図に示す如く、凹部2の開口部に被処理体3の周縁部を支持する平坦な支持段部2aを形成した加熱基台5も開発されている。この加熱基台5は、第1図に示す加熱基台4に比べてスリップの発生を抑えることができるが、依然被処理体3の径が大きくなると、十分にスリップの発生を抑えることができなかった。

〔発明の目的〕

本発明は、被処理体にスリップが発生するのを阻止して、所望の気相成長処理を容易に施すことができる加熱基台を提供することをその目的とするものである。

〔発明の実施例〕

以下、本発明の実施例について図面を参照して説明する。

この加熱基台10は、基体11の所定領域に

半導体ウエハ等からなる被処理体１２の径よりも僅に大きい径Ｚの開口部１３を有している。開口部１３の内壁には、被処理体１２の下面を支持する略環状の支持面１４を有して開口部１３内に突出した段部１５が形成されている。段部１５で囲まれた開口部１３の床面１６は、略平坦面に形成されている。基体１１としては、カーボン材料等からなる素材の表面にC.V.D.（Chemical Vapor Deposition）法等により炭化ケイ素を１００μm程度形成したものを使用するのが望ましい。炭化ケイ素を表面に形成するのは、後述する気相成長処理の際の温度が1000〜１２５０℃と高温に達した場合にカーボン材料からなる素材から、不純物が放出されるのを防止するためである。開口部１３の径Ｚを被処理体１２の径よりも僅に大きくしたのは、開口部１３内への被処理体１２の出入操作を容易にするためと、気相成長処理の際の温度によつて膨張した被処理体１２と基体１１とが接触して、被処理体１２に熱歪が生じるのを防止するためである。支持面１４の幅Ｌは、被処理体１２の直径の約５％の幅の縁部が支持面１４で支持されるように設定するのが望ましい。基体１１の表面から支持面１４までの距離X_1は、被処理体１２の肉厚に略等しく設定するのが望ましい。支持面１４から床面１６までの距離X_2は、被処理体１２の大きさに応じて適宜設定するのが望ましい。例えば、被処理体１２であるウエハの径が１００mmφの場合には、５０〜１００μm に設定するのが望ましい。この床面１６までの距離X_2を深くしすぎると、基体１１から被処理体１２に伝導する熱量が不十分になり、被処理体１２の温度を所定温度に設定できない。また、この床面１６までの距離X_2が浅すぎると、加熱された被処理体１２全体の温度を均一に保持できず、熱歪を発生したり或は欠陥を発生する原因となる。また、この床面１６までの距離X_2は、気相成長処理の際の加熱温度が、処理ガスとして$SiHCl_3$を使用した場合は１１５０℃、SiH_2Cl_2を使用した場合は１１００℃、SiH_4を使用した場合は１０００℃と異なるので、処理ガスの種類に応じても適宜設定するのが望ましい。また、床面１６の平坦度は、加熱された床面１６の熱が被処理体１２の下面全域に亘つて均一に伝わるように、被処理体１２の下面と略平行に設定するのが望ましい。床面１６に多少の凹凸が形成されていたり、或は、湾曲部が形成されていても、床面１６から被処理体１２の下面に均一に熱を伝達できればよい。また、段部１６は、開口部１３の内壁から開口部１３内に向つて突出して、被処理体１２を高い精度で支持できるものであれば良い。段部１５が構造的に環状に連つていることを特に要しない。また、床面１６から立設した段部１５の側面１７は、床面１６から被処理体１２への均一な熱伝達作用を助長するように、床面１６に対して約９０°の急峻な角度で立設していることが望ましい。

而して、このように構成された加熱装置１０によれば、開口部１３内に被処理体１２であるウエハを、その下面の縁部が支持面１４にて支持されるようにして収容し、これを所定の処理ガスが満された気相成長処理炉内に設置して気相成長処理を施す。炉内の加熱処理によつて、まず、基体１１全体の温度が急上昇する。この熱は、基体１１の段部から支持面１４を介して被処理体１２の縁部に伝達される。被処理体１２の周縁部では、段部１５が床面１６に対して急峻な角度で立設し、支持面１４に密着しているので、急激に温度上昇が起き、被処理体１２全体を加熱する熱が貯えられる。貯えられた熱は、被処理体１２の周縁部からその肉厚全体の領域に亘つて被処理体１２の中心に向つて拡散する。この被処理体１２内での熱拡散の際に、被処理体１２の表面は、炉内雰囲気に接した状態であり、裏面は、開口部１３の下部の中空部に接した状態になつているので、基体１１外からの熱の伝達は殆んど無視され、被処理体１２全体の温度が極めて均一な状態で上昇する。その結果、被処理体１２の縁部にあえて集中的にスリ

ップを発生させ、桟部を除いた領域にスリップが発生するのを阻止することができる。しかも、被処理体１２の温度上昇に伴って発生した熱歪は、被処理体１２の周縁部の領域に吸収されるので、更に、被処理体１２の中心部でのスリップの発生を阻止する作用を高めることができる。

因に、第３図に示す如く、基体１１の表面から支持面１４までの深さX_1を６５０μm、支持面１４から床面１６までの距離X_2を８０μm、床面１６の大きさを９０mmφ、開口部１３の径を１０２mmφに設定した加熱基台１０を用いて、この開口部１３内に被処理体１２である直径１００mmφのウエハを収容し、気相成長処理を施したところ支持面１４に接触しなかった領域（被処理体１２の周縁部を除いた領域）では、シルトルエッチング検査により、欠陥の有無を調べたところ、スリップの発生は殆んど見られなかった。この場合のスリップの発生数を被処理体１２の直径方向に沿って調べたところ、第４図(A)に示す通りであり、被処理体１２の周縁部に集中していることが判る。これに比べて球面状の開口部を有する従来の加熱基台では、第４図(B)に示す如く、被処理体の殆ど全域に亘って多数のスリップが発生していることが判る。更に、実施例の加熱基台１０に比べて桟部１５の突出量を多くして被処理体１２の中心から直径にして約６０mmφの領域が支持面と接触しないようにした加熱基台を使用すると、スリップの発生数は第４図(C)に示す如く、被処理体１２の中心から直径約６０mmφの領域を除いた周縁部全域で多数のスリップが発生していることが判る。つまり、実施例の加熱基台１０では、床面１６を略水平面にし、床面１６に対して急峻に立ち上がった桟部１５の支持面１４で被処理体１２を支持することにより、支持面１４に接触した被処理体１２の領域にのみスリップを集中的に発生させ、支持面１４に接触しない領域には、スリップを事実上発生させないようにすることができることが判る。

〔発明の効果〕

以上説明した如く、本発明に係る加熱基台によれば、被処理体内にスリップが発生するのを阻止して、所望の気相成長処理を容易に施すことができる等顕著な効果を奏するものである。

4.図面の簡単な説明

第１図及び第２図は、従来の加熱基台の断面図、第３図は、本発明の一実施例の断面図、第４図(A)乃至同図(C)は、スリップの発生数と被処理体の位置との関係を示す説明図である。

１０…加熱基台、１１…基体、１２…被処理体、１３…開口部、１４…支持面、１５…桟部、１６…床面、１７…側面。

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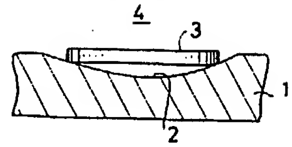
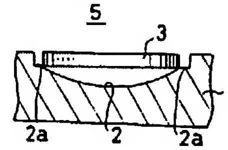
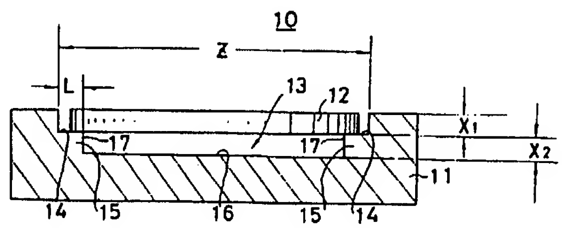
第 1 図



第 2 図



第 3 図



第 4 図